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Effect of water exercise on balance and related factors in older people

Fifteen subjects enrolled to take part in a water exercise programme (mean age = 69.7 years) and 13 control subjects (mean age 72.6 years) underwent assessments of quadriceps and ankle dorsiflexion strength, reaction time, neuromuscular control, body sway, flexibility and joint pain. All subjects were then retested for the same measures after completion of the nine-week programme. The experimental subjects showed improved quadriceps strength and reduced body sway when compared with the control group. There was also a trend towards increased flexibility, improved reaction times and reduced joint pain in the experimental group.

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A number of studies have shown that land-based exercise can improve physiological measures such as muscle strength, balance, reaction time and joint flexibility in older persons (Aniansson et al 1984, Morey et al 1991, Munns 1981). There are, however, few reports on the effect of water exercise on such measures.

One study, which included both pre and post tests (Danneskiold-Samsoe et al 1987) found a two month trial of twice weekly water exercise significantly improved isometric and isokinetic quadriceps strength in eight persons aged 35 to 66 years with rheumatoid arthritis. In another uncontrolled study, Smit and Harrison (1991) found that a four week trial of hydrotherapy had a beneficial effect on lower back pain and spinal mobility in 20 subjects of mean age 59 years (SD = 14.3) who were suffering from chronic lower back pain.

In an evaluation of a water exercise programme for frail elderly people, Rissel (1987) found that most of the 51 participants who completed the trial reported increased fitness, improved body tone and reduced stiffness. Participants also showed significantly improved scores on a scale of affect, reported that they felt more relaxed and calm, and stated that they enjoyed the programme, socialised and made new friends. Weiss and Jameson (1987) have also found that water exercise programmes enhance social interaction and have beneficial effects on affect.

Water exercise provides a viable alternative for older persons who are unable to participate in land-based exercise programmes because of impairments to balance or other disabilities. The buoyancy of water allows some elderly people to undertake exercises and movements that they could not do on land. Buoyancy and water pressure can also be utilised as resistance in strengthening exercises (Golland 1981).

Reduced mobility and independence and increased risk of falls in older people have been associated with impairments in strength, co-ordination, postural stability and flexibility (Campbell et al 1989, Lord et al 1991a, Whipple et al 1987). Thus it is of considerable importance to determine whether water exercise, which has been advocated as a means of improving or maintaining functional performance in older people, has beneficial effects on these physiological parameters.

This paper examines the effect of a nine-week pilot programme of water exercise on muscle strength, neuromuscular control, reaction time, body sway, flexibility and joint pain in a group of older persons, comparing these outcomes with age and gender matched controls.

Method

Subjects

Fifteen persons participating in their first water activity programme and 13

From Page 217

control subjects took part in the study. There were two men in each group. The water activity group was recruited from persons on a waiting list for the programme, whilst the controls were recruited from members of an adult learning and leisure activity (ALERT) group who met weekly at a senior citizens centre. Those in the ALERT group attended classes on current affairs and Australian history and took part in activities such as painting and craft. The mean age of the water activity group 69.7 years (SD=8.6), was not significantly different to the mean age of the controls, 72.6 years (SD=8.7), (t_{26}=0.88,p=0.39).

The water activity and control groups were similar across a number of health and lifestyle measures. Table 1 shows the numbers and proportions in each group who reported medical conditions, drug use, inactivity, falls, use of walking aids and disability. The proportion with diabetes was significantly higher in the control group, but all other measures showed no significant differences. The presence of one or more of these conditions did not preclude any of the water activity subjects from undertaking the exercise programme.

Exercise programme

The WAVES (Water Activities for Vitality in the Eastern Suburbs) programme, comprised the intervention. This programme, which was specifically designed for older people, consisted of one hour sessions, conducted once a week for nine weeks. The exercises were undertaken in the months of February, March and April in pools where the temperature ranged from 25 to 29 degrees C. Major aims of the programme were: to instil water confidence, to increase body flexibility and joint range of motion, to improve postural awareness, balance and co-ordination skills, to increase muscle strength and endurance, to enhance social contacts and maximise enjoyment (Rissel 1987).

Physiotherapists and trained water exercise leaders used a standard exercise warm-up, conditioning and cool-down period (American College of Sports Medicine 1980) modified for the target group and the medium of water. Participants of differing physical disabilities were encouraged to work at their own pace. The typical class format is outlined in Figure 1.

1. Warm up period.
- ▲ Stretching of all joint and major muscle groups.

2. Conditioning period – exercises.
- ▲ balance/co-ordination activities requiring participants to perform various movements with one leg and the arms whilst balancing on the other leg.
- ▲ weight transference/reaching activities challenging participants to go to the limit of single limb balance in different directions.
- ▲ fast walking, side-stepping and walking backwards the length of the pool whilst performing arm movements.
- ▲ a variety of upper limb range of movement exercises, such as moving the arms through or across the surface of the water (performed in a static half squat position or with gentle jogging on the spot).
- ▲ resisted upper limb exercises using a flexible foam rubber knee-board held with both hands (eg pushing the board down or away from the body through the water).
- ▲ hip, knee and ankle range of movement combinations performed either holding onto the side of the pool, balancing on one leg or in circle formation with participants holding hands.
- ▲ other activities including: kicking legs whilst holding a kick-board, hopping and jumping in circle formation, balance and co-ordination activities undertaken in pairs and team games such as over ball and relays.

Cool down period.
- ▲ Stretching, deep breathing and floating (with assistance if necessary) for 5-10 minutes.

Figure 1.
Exercise class format.

Sensori-motor function and flexibility assessments

The assessment, conducted prior to the commencement of the exercise trial, included tests of muscle strength, reaction time, neuromuscular control, body sway, flexibility (passive ankle dorsiflexion) and joint pain. Each full assessment took approximately 30 minutes. Subjects were re-assessed on all of the test measures at the end of the eight week programme by the same research personnel.

Quadriceps strength was measured by placing a strap around the subjects' dominant leg, ie the right leg in a right-handed person and the left leg in a left-handed person. The strap was connected to a fixation point behind a chair so that when the subject (seated on the chair) attempted to extend the leg, a spring gauge was extended, giving a measure of maximal quadriceps strength. The subject had three experimental trials and the greatest force measured by the spring gauge was recorded (in kg).

Ankle dorsiflexion strength was measured by having the subject place the dominant foot on a foot rest. A strap (which protruded through the foot rest) was placed over the foot just proximal to the little toe. The strap was connected to the base of the foot rest so that when the seated subject attempted to dorsiflex the foot (whilst keeping the heel placed on the foot rest) a spring gauge was extended, giving a measure of maximal ankle dorsiflexion strength. The subject had

Table 1.
Number and proportion who reported medical conditions drug use, inactivity, instability and disability.

	WAVES N	WAVES (%)	Controls N	Controls (%)
Poor or fair health[1]	4	(26.7)	4	(30.8)
Medical conditions				
Osteoarthritis	9	(60.0)	9	(69.2)
High blood pressure	5	(33.3)	5	(38.5)
Angina	5	(33.3)	4	(30.8)
Foot problems	4	(26.7)	5	(38.5)
Stroke	3	(20.0)	0	(00.0)
Diabetes	0*	(00.0)	4	(30.8)
Drug use				
3+ drugs	9	(60.0)	8	(61.5)
CVS drugs	10	(66.7)	7	(53.8)
CNS drugs	3	(20.0)	6	(46.2)
NSAIDS	7	(46.7)	4	(30.8)
Inactivity				
No planned walks[2]	7	(46.7)	7	(53.8)
Walk < 15 mins[3]	6	(40.0)	6	(46.2)
Instability				
1+ falls in past year	4	(26.7)	5	(38.5)
Uses walking aid	5	(33.3)	4	(30.8)
Disability				
Uses community services[4]	2	(13.3)	2	(15.4)
ADL limitations[5]	9	(60.0)	4	(30.8)

* – $p < 0.05$
1 – subjective health rating.
2 – never goes on planned walks for exercise.
3 – can walk no more than 15 mins before resting.
4 – uses one or more of: meals on wheels, home help, community nursing, shopping service.
5 – requires assistance with one or more of: shopping, clothes washing, house cleaning, cooking.

three experimental trials and the greatest extension of the spring gauge was recorded (in kg).

Reaction time was assessed with a simple reaction time paradigm, using a light as the stimulus and depression of a switch (by the foot) as the response. Subjects were given 10 practice trials and 10 experimental trials. The mean score of the 10 experimental trials was taken as the measure of reaction time.

Neuromuscular control was measured using a device that measured the subject's ability to press and depress a switch with the foot as many times as possible in a period of eight seconds. The seated subject placed the dominant foot on a foot rest which was hinged to a base plate. A switch recorded how many times the foot rest was depressed. The subject had a number of practice trials with the device, and then attempted to press and depress the foot as quickly as possible for eight seconds. Two experimental trials were performed with the higher number of foot depressions taken as the measure of neuromuscular control.

Body sway was measured using a sway meter that measured displacements of the body at the level of the waist. The device consisted of a rod attached to the subject at the waist level by a firm belt. A pen attached to the end of the rod recorded the movements of the subject on a sheet of graph paper (with a millimetre square grid) which was fastened to the top of an adjustable height table. The subject was instructed to stand with feet together on a firm base as motionless as possible for a period of 30 seconds while fixating a point at eye level at a distance of three metres. The test procedure was then repeated under a further three conditions: standing on a firm base with the eyes closed; standing on high density foam rubber (70cm by 62cm by 15cm thick) with the eyes open; and standing on the foam rubber with the eyes closed. The foam was used to reduce proprioceptive input from the ankles so that subjects were required to rely on visual and/or vestibular cues to maintain a steady stance (Lord et al 1991b, Ring et al, 1989). Total sway (number of square millimetre squares traversed) in the 30 second period was recorded for the four test conditions.

Passive ankle dorsiflexion was measured with the Lidcombe Template (Moseley and Adams 1991). In this test, the subject was seated on an examination couch with the right leg outstretched, but supported by a 10cm diameter cylinder placed under the knee. The head of the fifth metatarsal, lateral malleolus and head of the fibula were marked with a felt pen. The leg was then secured in

From Page 219

position with a Velcro strap. The tester applied a known dorsiflexion force (12kg) with the template and whilst the ankle was subjected to this force, a photograph was taken from a standard position (distance and height). The angle between the line connecting the head of the fifth metatarsal and the lateral malleolus and the line connecting the head of the fibula and the lateral malleolus was marked on the photograph and this angle was taken as the measure of passive ankle dorsiflexion.

Assessment of joint pain

Assessment of joint pain was made using the Absolute Visual Analogue Scale (AVAS) measure of pain sensitivity (Huskisson 1983, Zusman 1986). In this test, subjects indicated the overall intensity of pain experienced in their most painful joints on the day of assessments by marking on 10cm lines bounded with verbal descriptors no pain and pain as bad as it could possibly be. Joints and joint groups assessed included the neck, upper back, lower back, left shoulder, right shoulder, left hip, right hip, left knee, right knee, left ankle and right ankle. Subjects nominated up to three painful joints.

Test-retest reliability

Test-retest reliability co-efficients for the tests of muscle strength, reaction time, neuromuscular control and body sway have been obtained from a separate study of 36 subjects aged 50 to 75 years (mean age 62.5 years) (Lord et al, in press). In this study the tests were re-administered two weeks after initial assessments. The reliability co-efficients were high for tests of this nature, ranging from $r = 0.57$ to 0.92. Moseley and Adams (1991) also reported good reliability for the test of passive ankle dorsiflexion. In contrast, Dixon and Bird (1981) have reported that reproducibility of scores on the visual analogue scale is variable along its length. They suggested that whilst the scale allows pain assessments to be made anywhere along a continuum, subjects tend to grade their responses

Table 2.
Mean values (SDs) for the test measures at pre-test.

	WAVES (N=15)	Controls (N=13)
Quadriceps strength (kg force)	19.1(9.8)	20.9(6.5)
Ankle strength (kg force)	4.6(1.4)	4.0(1.4)
Reaction time (msecs)	299(69)	323(71)
Neuromuscular control (taps/8 secs)	30.6(6.4)	30.7(9.0)
Sway (mm squares traversed in 30 secs)		
Eyes open (floor)	116(75)	106(39)
Eyes closed (floor)	162(98)	151(103)
Eyes open (foam)	194(106)	133(49)
Eyes closed (foam)	216(106)	230(115)
Passive ankle dorsiflexion (degrees)	99.7(12.9)#	99.0(13.1)
Most painful joint (cm)	3.7(3.3)#	2.1(2.9)
Total joint pain (cm)	6.3(6.9)#	3.1(4.8)

All differences between groups $p > 0.05$.
#n = 13

in three areas: mild, moderate and severe. A classification based on improvement or no improvement was used in this study in the assessment of any change at re-test.

Statistical analysis

The sensori-motor measures were coded as continuous variables. Each of these variables had right skewed distributions so logs of variables were calculated. Student t tests were used to compare the means of the log (sensori-motor test measures) between the WAVES and control group at initial assessment and to compare any differences in performance at the end of the programme between the two groups. Chi square tests for cross-tabulation tables were used to assess improvement in joint pain between the groups. The data were analysed using the SPSS computer package (SPSS Inc 1990).

Results

Attendance

The mean number of classes attended was 7.2 (80 per cent). The range was from 5-9 classes (56 - 100 per cent). The number of sessions attended was not significantly associated with any degree of improvement in any of the sensori-motor test measures, flexibility or joint pain.

The mean values plus standard deviations for the test measures at initial assessment for the WAVES and control groups are shown in Table 2. None of the measures were significantly different at baseline, although there was a trend for the WAVES subjects to report greater levels of joint pain and to exhibit greater sway on the foam with eyes open.

Sensori-motor function and flexibility

Percentage changes from initial scores for the test measures for the WAVES subjects and the controls are shown in Table 3. Compared with initial results, the WAVES subjects showed improvements in all test measures except neuromuscular control, where the mean score remained virtually unchanged. The control subjects

Table 3.
Percentage change at re-test where re-test score is reported as percentage of baseline score.

	Waves	Controls
Quadriceps strength	112.9*	96.5
Ankle strength	106.4	107.3
Reaction time	93.9	98.1
Neuromuscular control	100.2	93.8
Sway		
Eyes open (floor)	83.5*	106.2
Eyes closed (floor)	74.2*	106.1
Eyes open (foam)	76.2**	129.8
Eyes closed (foam)	84.9	109.9
Passive ankle dorsiflexion	97.3	101.0

Increases in the tests of strength and neuromuscular control, and decreases in the tests of reaction time, sway and passive ankle dorsiflexion indicate improvements.
* $p<0.05$
** $p<0.01$

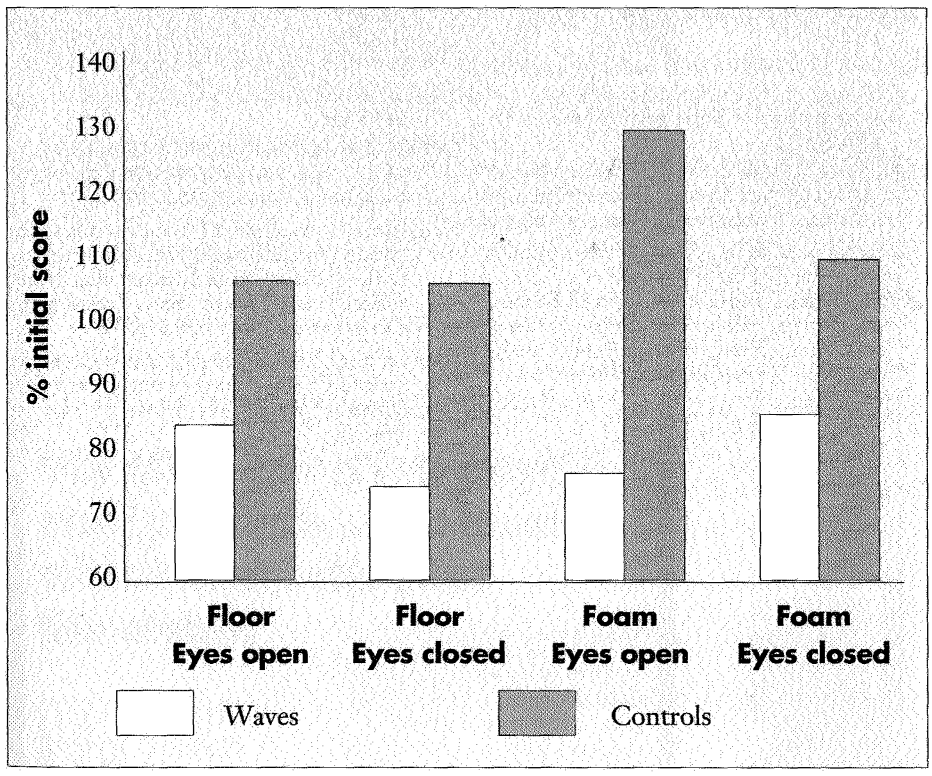

Figure 2.
Percentage change in body sway at re-test.

recorded very similar scores at re-test for the tests of passive ankle dorsiflexion, quadriceps strength, reaction time and neuromuscular control. Ankle dorsiflexion strength showed an increase of 7 per cent which might have been due to a practice effect. In contrast, body sway scores, particularly sway on the foam with eyes open, were higher at re-test.

When comparing percentage changes in performance between the groups, the WAVES subjects showed significantly improved performance in the tests of quadriceps strength, body sway on a firm surface with the eyes open and closed and body sway on the compliant surface with the eyes open. Reaction time, passive ankle dorsiflexion and sway on the compliant surface with the eyes closed also showed greater percentage improvements at re-test, although the differences were not statistically significant. Figure 2 shows the percentage changes in performance in the sway tests for the two groups at re-test.

Joint pain

Twelve WAVES subjects and 10 controls had joint pain at initial assessment. Seven of the WAVES subjects (58.3 per cent) reported that pain in their most painful joint had decreased by 50mm or more on the AVAS scale compared with five of the control subjects (50 per cent) (x^2=0.15,p=0.69). Seven of the WAVES subjects (58.3 per cent) reported pain in the sum of their three most painful joints had decreased by 50mm or more on the scale compared with only four of the control subjects (40 per cent) (x^2=0.73,p=0.39).

Discussion

The WAVES group showed significant improvements in the tests of strength and body sway following the programme, compared with a control group which was well matched in terms of age, gender, prevalence of diseases and disorders and performance at initial testing. The increase in strength in those undertaking the

From Page 221

water exercises is in accordance with the study by Danneskiold-Samsoe et al (1987). There was also an indication that the WAVES subjects showed improvement in passive ankle dorsiflexion and reaction time. The exercise programme and testing procedures were found to be safe, with no medical incidents occurring and, as with previous studies, the WAVES participants reported that they enjoyed the classes.

Notwithstanding these positive outcomes, it may be that the beneficial effects of water exercise are under-estimated by this pilot trial. The WAVES subjects were assessed after only nine weeks of classes, which may not be sufficient time to maximise improvement in flexibility and sensori-motor function. In addition, the sample sizes might have been too small to reveal significant differences between the groups in some test measures such as flexibility and reaction time. Power analyses (using the current study findings) revealed that groups of 120 would have revealed significant differences for these measures.

Future studies could also assess the value of including balance tests in the water, which would be useful for gauging progress throughout the intervention. They may also be useful predictors of stability and risk of falling on land.

Conclusion

Despite the limitations of this study, the findings suggest that water exercise can offer older people with moderate disabilities a means of keeping physically active by improving physical function measures such as body sway and strength. Further studies, aimed at assessing programmes of longer duration and greater frequency, which use larger samples, may give clearer indications of the maximal beneficial effects of water exercise.

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